Policy Implications of Excess Commuting: Examining the Impacts of Changes in US Metropolitan Spatial Structure

Jiawen Yang

Urban Stud 2008 45: 391
DOI: 10.1177/0042098007085969

Urban Studies
45(2) 391–405, February 2008

Policy Implications of Excess Commuting: Examining the Impacts of Changes in US Metropolitan Spatial Structure

Jiawen Yang

[Paper first received, December 2006; in final form, April 2007]

Abstract

This article examines how changes in US metropolitan spatial structure lead to an increase in measurable excess commuting and a decrease in measurable transport–land use connections. Using Boston and Atlanta as two comparative regions, this research computes excess commuting with three-decade census data and then examines excess commuting in relation to the changes in metropolitan spatial structure. Empirical results suggest that the transport–land use connection appears weaker over the decades as the dispersion of jobs changes the dynamics of commuting and the selection of residential location follows patterns of average job location rather than that of the closest available job location. This decreasing transport–land use connection points to a spatial structure effect apart from individual preferences. It also suggests an alternative view of excess commuting for metropolitan transport policy-making.

1. Introduction

It is widely known that workers do not select housing location as close to their current job location as possible. That is to say, commuting happens in excess of the minimum required amount. While this excess commuting may or may not be considered wasteful (White, 1988; Hamilton, 1989), it has certainly contributed to many discussions about the social implications of commuting as well as transport efficiency (Ma and Banister, 2006). This article does not challenge any existing conceptual interpretation of excess commuting, but adds another dimension: even without any 'spatial mismatch' problem, a spatial decentralisation process can lead to an increase in measurable excess commuting. This pure spatial effect implies an alternative view of excess commuting for transport policy-making.

Jiawen Yang is in the Program of City and Regional Planning, Architecture Building East, Georgia Institute of Technology, Atlanta, GA 30332-0155, USA. Fax: 1 404 894 1628.
E-mail: jy78@mail.gatech.edu.

0042-0980 Print/1360-063X Online

DOI: 10.1177/0042098007085969

Excess commuting is generally estimated as the differences between the observed amount of commuting and a theoretical minimum amount of commuting suggested by the job–housing relationship. The theoretical minimum has been used as a benchmark when examining commuting efficiency in metropolitan areas (Scott *et al.*, 1997; Horner, 2002; Niedzielski, 2006). If a high percentage of commuting is 'unnecessary', commuting length could then be reduced by encouraging workers to switch residences. Commuting efficiency can be improved without changing the physical patterns of land uses. One of the example policies is the "Live where you work" programme created in Baltimore, Maryland. The city government tries to encourage homeownership in the city by subsidising the cost of home purchasing in the city.

The same excess commuting, however, can be interpreted entirely differently. If a big portion of commuting can be quantified as excessive in relation to the land use pattern, a natural extension is that commuting plays a weak role in location decisions and urban growth strategies that change the spatial patterns of workplace and residence would be ineffective in inducing changes in commuting (Giuliano, 1995; Giuliano and Small, 1993). The quantified excess commuting, therefore, is also a measure of the strength of the transport–land use connection. An increase in excess commuting could be a sign of a weakening transport–land use connection. Excess commuting could be used to argue against urban growth strategies for congestion relief.

The case, however, would be different from either of the above two if an increase in excess commuting stems from spatial changes apart from individual preferences. For example, one of the most significant urban growth trends in recent decades has been the change from monocentric to dispersed regions (Gordon and Richardson, 1996). If this structural trend alone can increase excess commuting, a weakening transport–land use connection is the result of the urban growth trend. Urban growth strategies that reverse this trend can not only tighten the land use-transport link, but also induce commuting changes. In addition, if the increase in measurable excess commuting in recent decades is attributed to metropolitan structure evolution rather than to individual preferences, policies that aim to change individual location selection behaviour without changing the physical land use patterns will be unlikely to generate significant benefits for society.

In examining excess commuting or transport–land use connections, existing studies have emphasised individual preferences embedded in social and economic stratification (Ma and Banister, 2006). For example, Giuliano (1995) has emphasised the uneven distribution of neighbourhood characteristics, pointing out that the preference for safe neighbourhoods and high-quality education has lowered the importance of commuting cost and job–housing proximity. Cervero and Landis (1995) have emphasised the hidden subsidy in travel cost, pointing out that current transport policies have set automobile drivers' perceived travel cost much lower than the true cost, thereby lowering the importance of travel distance and weakening transport–land use connections.

The spatial dimension of excess commuting has also been noted. The basic idea of the 'spatial mismatch' is that certain low-skill jobs have moved to the suburbs while minority workers who could fill those jobs remain in the central city (Holzer, 1991). The spatial process is mainly presented as the manifestation of a social process characterised with different location selection by different firms and different households. When computing excess commuting, if jobs and employed residents are broken into different categories, spatial mismatch tends to increase the minimum required amount of commuting and lowers measurable excess commuting. Various socioeconomic factors, therefore, have been emphasised when explaining commuting length or estimated excess commuting. Corresponding policies—for example, making suburban housing affordable to central-city low-income households—have been proposed. Researchers have rarely studied the notion that excess commuting could change even though there was no problem of spatial mismatch or individual preference change in the spatial decentralisation process.

The hypothesis of a pure spatial effect, however, appears to be conceptually correct. In an extreme monocentric region where all jobs concentrate in a single centre, observed commuting length should be the same as the minimum required amount. Total commuting cannot be reduced by exchanging residences between any two employed residents, indicating zero 'excess commuting'. Since a monocentric region has no excess commuting and a diversion from the extreme monocentric scenario is a precondition for excess commuting, a more general statement might be: the evolution of metropolitan spatial structures might affect the amount of excess commuting and the strength of the transport–land use linkage. If this hypothesis is also true from an empirical perspective, policy-makers may do well to rethink the policy implications of measurable excess commuting for the reasons already mentioned. Towards this end, this article examines excess commuting and the strength of transport–land use connections in two US metropolitan areas, Boston and Atlanta, from 1980 to 2000. The article presents measures for excess commuting and transport–land use connections. It explains how excess commuting changes in relation to changes in metropolitan spatial structure and then discusses policy implications.

2. Methods

Atlanta and Boston are two sizeable but contrasting regions. In 2000, Boston and Atlanta had similar-sized job and labour markets, around 2 million (Table 1). Atlanta and Boston are both growing regions with increasing commuting time. Among all US metropolitan areas with over 1 million residents, Atlanta is ranked highest in increase in commuting time in the 1990s and Boston is ranked seventh (McGuckin and Srinivasan, 2003). Their stories of growth, according to Yang (2005), are significantly different from each other. From 1980 to 2000, the growth of jobs and workers in Atlanta was about twice Boston's annual growth rate. Atlanta has a more dispersed pattern than Boston. The more dispersed Atlanta has longer commuting time and distance. These differences make it convenient to reveal the impacts of metropolitan structure changes.

2.1 Measuring Excess Commuting and Urban Spatial Structures

Testing the hypothesis requires measures for excess commuting (EC). By definition, EC is the difference between observed actual commuting (AC) and minimum required commuting (MRC). AC information is generally estimated with survey data. MRC is computed using an optimisation model. The MRC measure was first introduced by White (1988). MRC relies on a linear optimisation model that minimises total commuting cost by matching jobs and closest available employed residents. This model was widely used to study transport in a polycentric urban space and to understand why people commute more than is required by land use patterns (Horner, 2002; Rodríguez, 2004).

MRC is computed with the cost minimisation model, which finds out the assignment of workers to jobs that minimises the total travel cost across all assignments

$$\text{Minimise} \quad Z = \sum_i \sum_j c_{i,j} x_{i,j} \tag{1}$$

$$\text{Subject to} \quad \sum_j x_{i,j} = N_i \tag{2}$$

$$\sum_i x_{i,j} = E_j \tag{3}$$

$$x_{i,j} \geq 0 \tag{4}$$

where, N_i and E_i represent worker and job counts in tract i; $c_{i,j}$ is travel cost between tracts i and j; and $x_{i,j}$ represents the number of workers living in tract i and working in tract j.

The model can be expanded to account for additional spatial mismatch if workers and jobs are divided into sub-groups. O'Kelly and Lee (2005), Horner (2002), Giuliano and Small (1993) and Kim (1995) all disaggregate the problem by including various worker characteristics.

After solving this assignment model, the minimum value of Z, divided by the total number of employed residents, is the regional average MRC. MRC_i for zone i can be obtained by averaging the travel costs for the minimum travel assignment, weighted by the commuting flow, from zone i to all other zones (when zone i is viewed as a home site), or from all other zones to zone i (when zone i is viewed as a job site).

Note that MRC is derived from the distribution of job and housing opportunities. It does *not* depict how individuals actually commute. Neither is it affected by the change of actual commuting. Therefore, MRC measures urban spatial structures, not actual commuting behaviour. Compared with existing job–housing relationship measures such as gravity-type accessibility, which represents metropolitan structures with scores, MRC represents spatial structure in terms of travel cost, making it convenient to compare metropolitan structure changes and commuting outcomes (Yang and Ferreira, 2005).

In order to achieve the lowest cost, the MRC model matches jobs with the closest 'available' workers (or, alternatively, it matches workers with the closest 'available' jobs). Note that the MRC model does not necessarily match workers in a residential zone with the closest jobs because of the competition from other nearby workers. The averaged MRC value for residential sites, therefore, shows the distance to the closest 'available' jobs and MRC values mainly reflect local land use patterns. Localities with low-density development and exclusionary zoning tend to have higher MRC. MRC is also subject to regional influence, for the MRC flow minimises travel distance across the entire region. Therefore, MRC for a community reflects growth patterns within the community as well as those in nearby communities.

MRC, however, misses important regional aspects of the job–housing relationship. This point can be illustrated with a comparison of two contrasting urban spatial structures: a monocentric structure (with jobs and housing balanced in each zone and 90 per cent of jobs and housing contained in the urban core) and a completely dispersed structure (also with a local job–housing balance within each zone). These two spatial structures both have low MRC values, even though their regional structures are significantly different from each other. The lack of the regional aspect in MRC has been noted by researchers. Horner (2002) proposed a maximum commuting measure as an extension to the MRC measure. Yang and Ferreira (2007) proposed proportionally matched commuting (PMC) as a replacement for maximum commuting because of the behaviour implications.

With PMC, the assumed probability that any particular job in zone j is assigned to an employee living in zone i is proportional to zone i's share of the entire region's labour market. Hence PMC flows can be calculated using

$$x_{i,j} = \frac{N_i * E_j}{\sum E_j} \tag{5}$$

The proportional allocation assumption in the PMC approach is equivalent to assuming that every worker in the region competes for every job in the region, regardless commuting cost. That is, the PMC approach assumes that travel cost plays no role in location decisions. Since commuters are not deliberately wasteful, PMC is a reasonable replacement for maximum commuting.

After computing the PMC flow, the average travel cost weighted by the PMC flow is the PMC value for the entire region. Just as for MRC, we can compute a PMC value for a sub-region by averaging travel cost, weighted by commuting flow, into the sub-region from all zones (when the sub-region is viewed as a job location), or out of the sub-region (when it is viewed as a residential location).

Unlike MRC, PMC values reflect a region-wide view of the job and labour markets. PMC for a residential site gives the distance to an average job. Places that are closer to major centres tend to have lower PMC values than those farther away. Averaged for the region, the PMC value gives the distance from an average residence site to an average job.

In a numeric simulation, Yang and Ferreira (2007) find that PMC for a region increases steadily as the region moves from a monocentric structure to a dispersed structure. Yang (2005) uses the PMC measure in conjunction with the MRC measure to explain commuting time in Boston and Atlanta, and finds that the regional aspects of urban spatial structure represented by PMC are more influential in inducing commuting changes than the local aspects measured by MRC. Therefore, it is important to use PMC in addition to MRC in assessing metropolitan structure.

2.2 Data and Computation

Both Boston and Atlanta have Census Transport Planning Packages (CTPP) for 1980, 1990 and 2000. These datasets have a 20-year time-span, which offers the possibility of studying how metropolitan structure changes commuting dynamics. Metropolitan boundaries in both regions have changed over time. This research uses 1990 census definitions of metropolitan boundaries and cuts the 1980 and 2000 data to fit the 1990 boundaries. CTPP data summarise information by residence, by workplace and by workplace–residence pair. The data are spatially aggregated at levels of block groups, census tracts and traffic analysis zones. Census tracts are selected as the basic analysis units.

This computation of MRC and PMC requires two data items. First, job and worker counts for each census tract are extracted from the CTPP data. Secondly, a matrix containing travel distance between each pair of tracts is computed. Intertract travel distance is the shortest-route distance between census tract centroids, as previously calculated by Wang (2001). The selected road networks are extracted from ESRI GIS layers of major roads. The within-tract travel cost is the radius of a circle that has the same area as the census tract, as in Frost *et al.* (1998).

The MRC problem is then solved with LOQO, a general-purpose optimisation software.

After the computation of MRC and PMC flows, MRC and PMC values for each tract are calculated using the flow-weighted average travel distance for each tract by residence end. The results are MRC and PMC values for each residence tract. The result should be to some extent sensitive to the size and the shape of the analysis units. Analysis with census tracts as the basic units, however, is sufficiently disaggregated to produce a stable result that does not vary significantly with the configuration of the analysis units (Horner and Murray, 2002).

Since CTPP data also provide estimated actual commuting (AC) flows between each pair of tracts, an average AC distance is also calculated for each tract using the same approach of flow-weighted average. The EC value for each tract is then obtained by subtracting MRC from AC. These tract-level measures will be used in regression models.

Since it is useful to have a regional-level view before detailed examination, regional-level MRC, PMC and AC distances are also computed. The regional-level measures are the weighted average of tract-level measures. The weight is the number of employed residents in each tract.

3. Excess Commuting in Boston and Atlanta

Table 1 presents basic statistics for metropolitan Boston and Atlanta, including MRC, PMC, AC and EC by region average. The table also contains an item 'span', which is the difference between PMC and MRC. Detailed explanation of this item is presented in the next sub-section. Note that EC has increased all these years in both Boston and Atlanta, possibly indicating a weakening transport–land use connection.

Alternatively, a more systematic approach to measuring the strength of the transport–land use connection is the best-fit spatial decay factor (u) in the doubly-constrained gravity model below, where A_i and B_j are adjustment factors and equations (7) and (8) are residence and workplace constraints.

$$x_{i,j} = A_i B_j N_i E_j \exp(-u * c_{i,j}) \tag{6}$$

$$\sum_j x_{i,j} = N_i \tag{7}$$

$$\sum_j x_{i,j} = E_j \tag{8}$$

According to the entropy maximisation theory, the parameter u in this model represents the sensitivity to travel cost (Wilson, 1970). In the case of commuting, a higher u tells us that location decisions and the subsequent commuting pattern are more sensitive to commuting cost and thus shows a stronger link between local job–housing proximity and commuting. When u is zero (no impact from travel cost), the resulting commuting based on known job–worker counts is exactly PMC. When u approaches infinity (dominating impact from travel cost), the result is exactly MRC (Evans, 1973). Since travel cost actually has an impact somewhere between zero and approaching infinity, it is no wonder that

Table 1. Statistics for Boston and Atlanta metropolitan areas

	Boston			*Atlanta*		
	1980	*1990*	*2000*	*1980*	*1990*	*2000*
Employed residents (million)	1.83	2.07	2.15	0.94	1.43	1.90
Jobs (million)	1.70	2.20	2.31	0.72	1.40	2.00
AC: time (minutes)[a]	23.1	23.8	27.6	27.0	26.4	30.5
AC: distance (km)[b]	11.4	14.7	16.3	18.5	21.7	22.1
MRC (km)[c]	5.9	6.2	6.8	10.7	10.8	10.4
PMC (km)	27.2	36.5	37.5	26.2	34.9	41.7
Span (PMC–MRC)	21.3	30.3	30.7	15.5	24.1	31.3
Excess commuting (km)	5.5	9.1	9.5	8.8	10.9	11.7

[a]To exclude boundary effects, commuting time and distance are averaged for those who both live and work in the metropolitan area. The numbers here may be slightly different from other sources.
[b]This should be an underestimate for the actual commuting distance because I use the shortest-route distance as the replacement for actual commuting distance. However, this measure is still viable for our research purpose because the underestimate is consistent over time.
[c]MRC values in this table do not include market segmentation effects; these are presented later.

AC values fall between MRC and PMC in Table 1.

Since CTPP data provide information on actual commuting flow and job and worker counts, estimating the best-fit *u* values for the doubly constrained model adds a straightforward measure of the strength of the transport–land use connection. Multiple *u* values based on multidecade data can show how the link between commuting and the job–housing relationship changes over time. Figure 1 presents estimated *u* values for both Boston and Atlanta. The *u* values generally decrease over the decades, indicating a decreasing role for travel distance in location decisions.

The descriptive statistics in Table 1 and the estimated *u* values in Figure 1 depict a similar trend: the importance of travel cost has lowered in recent decades. Is this trend caused by the changing metropolitan structure? The following sections address this question in detail. Here, one can outline the changes in metropolitan structures. In Table 1, MRC is relatively stable in both Atlanta and Boston, but PMC increases significantly. In Boston, PMC increases from 27 km in 1980 to 37 km in 2000. In Atlanta, it is 26 km in 1980 and 42 km in 2000. These numbers indicate that as spatial decentralisation continues, an average employed resident lives increasingly far away from the average job location, although s/he lives within a stable distance to the closest available job.

4. Impacts of Metropolitan Structural Changes on Excess Commuting

4.1 The EC–PMC Connection

Regression models can help to demonstrate whether the increase in recent decades is caused by the spatial changes in metropolitan structures. Several simple models are presented in this section. These models use census tracts as analysis units and the tracts are treated as residence sites. The dependent variable is the computed average EC distance for workers

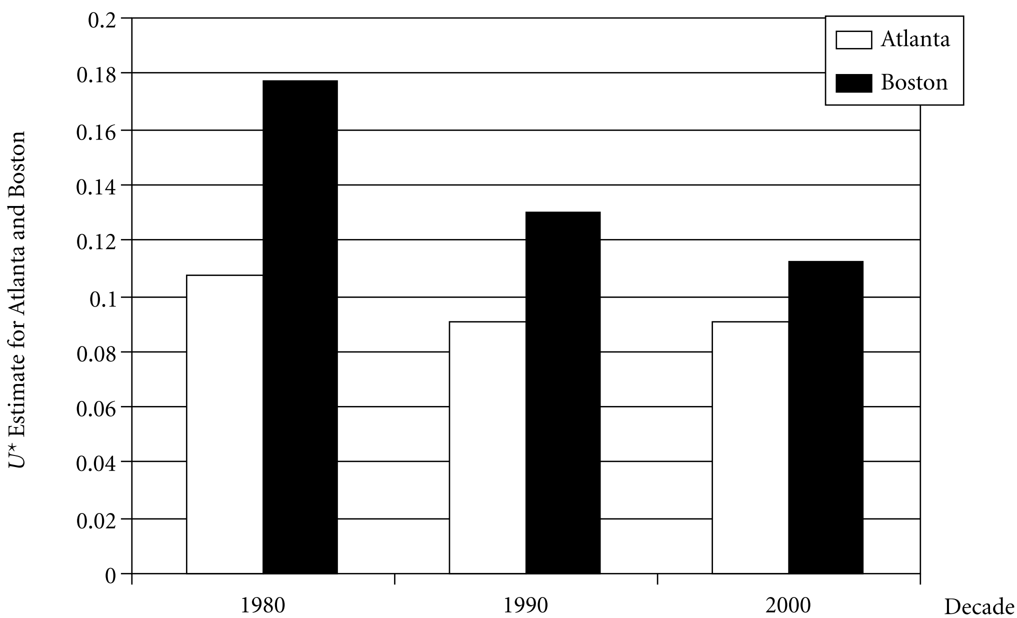

Figure 1. Sensitivity of location selection to travel distance (*u*).

living in each tract. MRC and PMC are the only two independent variables. MRC gives the distance to the closest available job location and PMC gives the distance to an average job across the region. Socioeconomic variables will be added in the next section.

These models have a zero constant because PMC and MRC become zero when all jobs and all workers collapse to a unique region centre. This hypothetical extreme situation eliminates commuting. Separate models are estimated for 2000, 1990 and 1980. The three models shown next use Boston data.

$$EC = -0.762 * MRC + 0.382 * PMC \ (2000)$$

$$EC = -0.685 * MRC + 0.330 * PMC \ (1990)$$

$$EC = -0.459 * MRC + 0.303 * PMC \ (1980)$$

Models of different years have slightly different estimates, but all the R^2 values are over 60 per cent (R^2 is 0.83 for 2000, 0.71 for 1990 and 0.62 for 1980) which indicates a strong association between EC and metropolitan structures from a spatial cross-sectional perspective. The positive coefficients for PMC indicate that EC is higher in residential sites where distance to an average job is greater. Also, note that EC is lower in residential sites where distance to the closest job (MRC) is higher. This makes sense because a high job–housing imbalance leaves less space for EC when the travel budget is limited. The three models for Atlanta, shown next, tell a similar story. Here, the R^2 values are 0.81 for 2000, 0.95 for 1990 and 0.97 for 1980. MRC and PMC are good predictors of the spatial variation of EC at the tract level.

$$EC = -0.730 * MRC + 0.448 * PMC \ (2000)$$

$$EC = -0.673 * MRC + 0.529 * PMC \ (1990)$$

$$EC = -0.606 * MRC + 0.552 * PMC \ (1980)$$

An interesting time-trend emerges as one compares the three models for a single region. In the Boston models, PMC plays an increasing role in predicting EC changes. The t-statistic increases from 32.8 in 1980 to 69.7 in 1990 and further to 101.9 in 2000. In a contrast, the relationship between EC and MRC is loosening. The t-statistic decreases from 18.4 in 1980 to 13.6 in 1990 and further to 13.1 in 2000. The same trends can be found in the Atlanta models, where the PMC t-statistic increases from 56.8 in 1980 to 74.4 in 1990 and 80.5 in 2000, while the MRC t-statistic decreases from 23.3 to 18.2 to 13.7 respectively. That is to say, the spatial variation of EC at the tract level increasingly follows the spatial patterns of PMC. This trend needs further explanation.

Since EC = AC – MRC, a regression equation $EC = a * MRC + b * PMC$ can be rewritten as $AC = (1 + a) * MRC + b * PMC$. The t-statistics for the two coefficients—$(1 + a)$ and b—in the AC models should be exactly the same as those statistics for a and b in the corresponding EC models. Therefore, to explain the EC–PMC linkage in the EC models is equivalent to explaining why AC increasingly follows PMC and decreasingly follows MRC in the AC models. A tentative perspective is the change in metropolitan structure.

It is always useful to use a hypothetical monocentric region as the starting-point for this conceptual exploration. In a region where all jobs are concentrated in the urban core and labour forces are distributed across the region, there is one and only one commuting possibility: everyone commutes from their selected residence to the single job centre. Actual commuting flow is the same as MRC flow and PMC flow. That is to say, EC is zero and distance to the average job is the same as the distance to the closest available job (MRC = PMC).

Numeric simulation for a stylised region indicates that imbalanced decentralisation tends to result in relative stable MRC and increasing PMC. The result is an increasing location flexibility measured by the span from MRC to PMC (Yang and Ferreira, 2007).

The same trend is observed in real regions (Table 1). In Atlanta, for example, the span increases from 15.7 km (26.2 – 10.7) in 1980 to 31.3 km (41.7 – 10.4). Since AC should generally fall between MRC and PMC, an average Atlantan (from a statistical perspective) in 1980 could select a residence located between 10.7 km and 26.2 km from his/her job location. In 2000, an average Atlanta person could select a residence located between 10.4 km and 41.7 km from the job location. This increasing location flexibility implies that workers could pay less attention to residences close to their jobs while making location decisions in decentralising metropolitan areas.

This possibility becomes a reality once we consider the fact that many commuters view job and housing location decisions as temporary rather than permanent. A worker could decide to take a job while anticipating that he will change his/her job in the future. A worker could also decide to buy a house while considering that the house will be sold in a future market. This nature of residence location decisions tends to increase the attractiveness of the average housing location rather than that of the closest available location, as proximity to a big job market implies potential to gain from housing appreciation or to save relocation when the worker switches to another job in the same region. As confirmed in an empirical study (Crane, 1996), the higher the job insecurity, the lower the proximity to the current job location and the longer the commuting.

Note that the issue here is not about whether this temporal nature of decision-making causes EC, but about the different consequences that result from the same decision-making nature in different spatial circumstances. In the monocentric region, to be close to many job opportunities is the same as to be close to the current job location, which is in the only job centre in the region. However, in a dispersed region with significant job decentralisation, to be close to many employment opportunities has a significantly different meaning. The more dispersed the employment opportunities, the higher the number of small job centres, the lower the share of the regional job stock in an average job centre, the lower the job share of the current job centre for an average worker, the lower the role played by the proximity to current job location and the higher the importance to be close to an average job location.

It is PMC that describes a residence's proximity to the region-wide average job opportunity. Therefore, as the region moves from monocentricity to dispersal, the AC–PMC link appears tighter and the link between commuting and local job–housing proximity appears weakened. Both Boston and Atlanta are on the evolutionary path from monocentricity towards dispersion (Yang, 2005). With a loosening linkage between AC and MRC, EC consequently increases.

This discussion has mainly considered new residence selection. However, it does not exclude those long-term residents who acquire new jobs well after establishing residency. Today's long-term residents were generally first-time home buyers decades ago. They also faced the same trade-off between being close to the current job location and being close to an average job location. The preference for residences close to an average job location decades ago lowers today's need to relocate while taking new jobs, thereby improving the residents' ability to remain in the same place.

4.2 Structural vs Social Effects

The simple models shown earlier do not address two counter-arguments: the time-trends in the simple regression models may occur only because socioeconomic factors such as job occupations are not controlled for; and the strengthening AC–PMC link may be a consequence of the increase in multiple-worker households. If a household has multiple workers in different job locations, the resulting residence location also tends to be closer to the average job location. In order to address these concerns, regression models that control for these factors have to be developed.

A skill mismatch variable is first computed in order to address job market effects. All job opportunities and employed residents are divided into two categories: high-skilled and low-skilled. The high-skilled group includes executive, administrative and managerial occupations; professional and specialty occupations; and technicians. All other occupations are classified as low-skilled. Then the minimum cost assignment is computed with a disaggregated model, as has been done in other studies (Horner, 2002; Giuliano and Small, 1993). Similar average MRC values are calculated for each census tract. Since the new averaged MRC values account for skills mismatch, it tends to be larger than the overall MRC presented previously. The difference between them represents a commuting penalty stemming from the spatial mismatch of different categories of jobs and labour force. This variable is therefore called 'skills mismatch'.

Various socioeconomic variables are also added, as in Shen (2000) and Wang (2001). These variables include the percentage of females in the workforce, the percentage of African American workers, the percentage of Hispanic workers, the percentage of households with at least two workers and the percentage of households with more than two workers. All necessary information is provided in the CTPP data. In addition, a variable of driving speed is added. CTPP data provide self-reported commuting time by mode. Average driving speed for employed residents from a tract is the ratio of tract-level AC distance to AC time for those commuting by driving alone. All the above variables help to control for effects from job occupations, gender, race, household structure and mobility.

A simple approach to integrating these factors is to add them into the above cross-sectional models. I do not use this approach because the issue here is not about the spatial manifestation of social impacts on commuting, but to what extent the EC increase over the decades can be attributed to the structural and social changes. It is the time-trend that matters. Therefore, I present regression models that account for incremental changes. The dependent variable is the AC distance change from 1980 to 2000 for each analysis unit. The independent variables are the change in MRC, the change in PMC, the change in mobility and the change in other socioeconomic variables. Coefficients in these models will tells us whether the incremental changes of AC can be explained with the incremental social and structural changes.

Because census tract boundaries change over time, the tract-level variables are aggregated to the municipality level for the Boston data, similar to the aggregation for regional-level MRC and PMC values. For Atlanta, all year 2000 variables are realigned to the year 1980 tract boundaries. After excluding non-values, 122 analysis units enter the Boston model and 320 census tracts enter the Atlanta model. Table 2 presents the regression results.

After controlling for socioeconomic factors, MRC and PMC, the two variables of metropolitan structure change, have significant t-scores in explaining AC distance changes. A place with a greater increase in MRC or PMC tends to have a greater increase in AC. On average, in Atlanta, a 1 km increase in MRC causes a 0.61 km increase in AC and a 1 km PMC increase causes a 0.15 km AC increase. In Boston, a 1 km increase in MRC leads to a 0.19 km increase in AC distance and a 1 km increase in PMC leads to a 0.59 km increase. Changes in the distance to closest available jobs and the distance to an average job both explain commuting changes.

Table 2. Regression results: AC impacts of metropolitan changes, 1980–2000

	AC distance change					
	Atlanta			*Boston*		
	Coefficients	*Standard error*	*T-statistic*[b]	*Coefficients*	*Standard error*	*T-statistic*[b]
Intercept[a]						
MRC	**0.61**	0.03	19.66	**0.19**	0.05	3.48
PMC	**0.15**	0.05	2.85	**0.59**	0.28	2.09
Skills mismatch	**0.67**	0.09	7.54	0.1	0.11	0.9
Percentage of HH with at least two workers	2.29	3.85	0.59	–14.42	14.7	–0.98
Percentage of HH with more than two workers	–1.89	3.86	–0.49	–7.72	23.56	–0.33
Percentage of female workers	0.1	1.51	0.07	18.79	22.56	0.83
Percentage of Black workers	0.93	3.19	0.29	3.53	9.61	0.37
Percentage of Hispanic workers	–1.16	1.95	–0.6	–14.55	13.73	–1.06
Driving speed	**0.17**	0.03	5.98	**0.35**	0.04	8.69
Number of analysis units		320			122	
R^2		0.67			0.56	

[a]Models are assigned a zero constant for the same reason mentioned in the previous section.
[b]A t-statistic with an absolute value greater than 1.96 is different from zero at the 5 per cent level of significance.

Note: Significant coefficients are shown in bold.

One may notice that coefficients for MRC and PMC differ between Atlanta and Boston. The Atlanta model has a greater coefficient for MRC but the Boston model has a greater coefficient for PMC. One possible explanation comes from the different MRC values for these two regions. MRC sets the minimum required amount of commuting effort. A higher MRC value suggests that a local job–housing imbalance imposes a stringent constraint on location decisions. In Boston, the relatively low (6 km) MRC does not impose a serious constraint on location decisions compared with the much higher MRC (over 10 km) in Atlanta. Therefore, AC distance change in Atlanta follows MRC changes more closely than in Boston.

Similar to the rearrangement of the previous simple models, models of EC changes can be derived. Since EC[2000] – EC[1980]= (AC[2000] – MRC[2000]) – (AC [1980] – MRC[1980])= (AC[2000] – AC[1980]) – (MRC[2000] – MRC [1980]), the models of EC changes have the same coefficients as the models of AC changes except for the coefficient for the variable of MRC changes. By subtracting 1 from MRC coefficients in the AC models, one can get MRC coefficients for the new models of EC changes. Since the MRC coefficients in Table 2 are smaller than 1, the new EC models will have negative coefficients for variables of MRC changes, which is meaningful because an increase in the job–housing imbalance squeezes out some excess commuting. Recall that MRC tends to be stable but PMC increases over the decades for both Boston and Atlanta, the increase in EC by region average, therefore, can be mainly attributed to PMC increase.

In contrast to the significant estimates for the structure change variables (MRC and PMC), the coefficients for the socioeconomic variables show mixed results. Only the skills mismatch variable in the Atlanta model has a significant coefficient. An increase in skills mismatch tends to increase EC and AC in the Atlanta region. One reason why the same variable may be insignificant in Boston could relate to the more spatially aggregated unit of analysis in Boston. It could also relate to the history of these two regions. In Atlanta, urban growth continues to fall in line with racial segregation in Atlanta. Fast growth has avoided the southern part where African Americans concentrate (Center on Urban and Metropolitan Policy, 2000). In Boston, significant spatial and social stratification had already happened before the study period (1980–2000). The changes during this period might not be significant enough to cause significant AC or EC changes. Also, coefficients in these models of incremental changes have different meaning from those in basic spatial cross-sectional models. The insignificance of many socioeconomic variables in these models of incremental changes does not suggest that the social stratification of commuting is disappearing from a cross-sectional perspective, as presented in other studies of Boston and Atlanta (Shen, 2000; Sultana, 2005).

5. Policy Implications of Excess Commuting

The empirical finding of this paper does not override existing discussion regarding EC and transport–land use connections, which has emphasised various socioeconomic factors, but adds another important dimension for considering EC. Researchers may have to take into consideration urban spatial structural changes when interpreting EC for transport policy-making, especially when the analysis involves multiple regions or a single region over different years. For example, the increase in EC in Table 1 does not necessarily suggest that individual preference is changing and leading to more wasteful commuting. Instead, it probably results from the same or stable individual preferences that guide decision-making in a changing spatial context of metropolitan structure. Neither does the apparently weakening transport–land use linkage represented by a macroscopic EC increase or *u* decrease suggest that the linkage is actually weakening from the perspective of individual behaviour. All these results might be misinterpreted if researchers only focus on the socioeconomic factors for individual decisions, but neglect the spatial structural change, which is the spatial context for decision-making. Without considering EC impacts of spatial changes aside from individual preferences, policy-making based on measurable EC could be misleading.

In addition, the discovery of impacts of metropolitan spatial structural changes on EC can help to resolve some controversy in the debate about commuting and transport–land use connections. As spatial decentralisation changes the dynamics of commuting and AC increasingly follows PMC, empirical studies based on measures of regional aspects of metropolitan spatial structure will be more likely to find significant transport–land use connections (Shen, 2000; Levinson, 1998; Wang, 2001) compared with those using measures of the local job–housing balance (Giuliano and Small, 1993; Cervero, 1996; Peng, 1997).

Most important of all, the revealed relationship between EC and spatial changes in metropolitan structure suggests that a weak transport–land use connection measured with EC does not necessarily imply the ineffectiveness of urban growth strategies. If transport–land use connection matters and EC is a problem, strategies of constrained spatial decentralisation or concentrated development can address it. By growing strong urban and suburban centres of housing and business, and by replacing many smaller job centres with several centres of a greater size, a worker's proximity to the current job location becomes more equivalent to being close to a large stock of jobs. The outcome will be a stronger MRC–AC linkage and a tightened transport–land use connection. This concentrated development can be achieved through redevelopment, infill development and densification in current activity centres.

The empirical results presented in this article do not address the extent to which concentrated development can shorten commuting, but it is useful to point out some additional differences between Boston and Atlanta. Boston has been more polycentric than the dispersed Atlanta in terms of spatial distribution of employment and residence (Yang, 2005). In the year 2000, Atlanta and Boston began to approach a similar size in terms of job opportunities, as shown in Table 1. The associated EC value is longer in Atlanta, indicating a weaker transport and land use connection in a more dispersed region. The estimated *u* value is also lower in Atlanta (Figure 1), also indicating a weaker connection there. Consequently, commuting time and distance are longer in Atlanta. This comparison indicates an association between alternative metropolitan structures, measurable excess commuting and average commuting length.

The implications of EC for urban growth strategies, therefore, may not centre on the effectiveness of urban growth strategies in general. Instead, the issue is more about selecting strategies carefully. Because of the weakening connection between AC and MRC in a decentralising region, a job–housing balance may be a necessary condition rather than a sufficient condition to increase commuting efficiency. Even though balanced development has the possibility of reducing MRC and then AC, the chance is rather limited. In examining the job–housing balance and commuting in Portland, Oregon, Peng (1997) finds that a local-balance approach can induce significant commuting changes only when the job–housing imbalance is extreme. What has changed the commuting dynamics is not the job–housing balance at the local level, but the job–housing relationship at the regional level. As dispersion increases the distance from an average residence to an average job, and the latter increasingly affects location selections, a strategy that aims to adjust the job–housing relationship from a regional perspective appears more attractive, particularly when local balance is also taken care of at the same time. Concentrated development belongs to this category.

6. Conclusions

Excess commuting could be attributed to various social, spatial and even psychological factors. These factors are usually mixed together and hard to discern. The empirical study of Boston and Atlanta demonstrates the likelihood that excess commuting can increase purely as a result of the spatial changes in metropolitan structures, aside from individual preferences. As dispersed development creates the gap between proximity to current job locations and proximity to the average job location, household location selection, even based on constant preferences, tends to gravitate towards the average job location. The result is an increase in measurable excess commuting.

This likelihood suggests an alternative view of excess commuting for metropolitan transport policy-making. Because of the change in location dynamics in a decentralising region, it is difficult to use excess commuting increases to argue against urban growth strategies. Instead, this increase in excess commuting suggests concentrated development as an urban growth strategy, which can not only tighten the transport–land use connection, but can also provide undersupplied transit-friendly communities. According to survey-based research by Levine *et al.* (2005) in Atlanta, a significant proportion (40 per cent) of respondents who state that they prefer to live in a transit- and walking-friendly neighbourhood actually do not live there. In Boston, as current spatial decentralisation leads to the increased dispersion of job and housing opportunities, the associated congestion and high housing cost have also sparked interest in regional planning. A recent poll finds growing support among local communities for regional cooperation on many issues, including the two traditionally local issues: housing and land development (MAPC, 2005). The freedom to choose housing and workplace, therefore, are still preserved when concentrated development only targets what is undersupplied.

References

Center on Urban and Metropolitan Policy (2000) *Moving beyond sprawl: the challenge for metropolitan Atlanta*. The Brookings Institution, Washington, DC.

Cervero, R. (1996) Job–housing balance revisited: trends and impacts in the San Francisco Bay Area, *Journal of the American Planning Association*, 62, pp. 492–511.

Cervero, R. and Landis, J. (1995) The transportation –land use connection still matters, *Access*, 7, pp. 1–10.

Crane, R. (1996) The influence of uncertain job location on urban form and the journey to work, *Journal of Urban Economics*, 39, pp. 342–356.

Evans, S. (1973) A relationship between the gravity model for trip distribution and the transportation problem in linear programming, *Transportation Research*, 7, pp. 39–61.

Frost, M., Linneker, B. and Spence, N. (1998) Excess or wasteful commuting in a selection of British Cities, *Transportation Research A*, 32, pp. 529–538.

Giuliano, G. (1995) The weakening transportation–land use connection, *Access*, 6, pp. 3–11.

Giuliano, G. and Small, K. A. (1993) Is the journey to work explained by urban structure?, *Urban Studies*, 30, pp. 1485–1500.

Gordon, P. and Richardson, H. W. (1996) Beyond polycentricity: the dispersed metropolis, Los Angles, 1970–1990, *Journal of the American Planning Association*, 62, pp. 289–295.

Hamilton, B. W. (1989) Wasteful commuting again, *Journal of Political Economy*, 97, pp. 1498–1504.

Holzer, H. (1991) The spatial mismatch hypothesis, *Urban Studies*, 28, pp. 105–122.

Horner, M. and Murray, A. (2002) Excess commuting and modifiable area unit problem, *Urban Studies*, 39, pp. 131–139.

Horner, M. W. (2002) Extensions to the concept of excess commuting, *Environment and Planning A*, 34, pp. 543–566.

Kim, S. (1995) Excess commuting for two-worker households in the Los Angeles metropolitan area, *Journal of Urban Economics*, 38, pp. 166–182.

Levine, J., Inam, A. and Torng, G. W. (2005) A choice-based rationale for land use and transportation alternatives: evidence from Boston and Atlanta, *Journal of Planning Education and Research*, 24, pp. 317–330.

Levinson, D. (1998) Accessibility and the journey to work, *Journal of Transport Geography*, 6, pp. 11–21.

Ma, K. R. and Banister, D. (2006) Excess commuting: a critical review, *Transport Reviews*, 26(6), pp. 749–767.

MAPC (Boston Metropolitan Area Planning Council) (2005) *The resonance of the region: a report on metrofuture polling and survey efforts*. MAPC, Boston, MA.

McGuckin, N. and Srinivasan, N. (2003) *Journey-to-work trends in the United States and its major metropolitan areas, 1960–2000*. Report prepared for US Department of Transportation.

Newman, P. and Kenworthy, J. (1999) *Sustainability and Cities: Overcoming Auto Dependence*. Washington, DC: Island Press.

Niedzielski, M. A. (2006) A spatially disaggregated approach to commuting efficiency, *Urban Studies*, 43, pp. 2485–2502.

O'Kelly, M. E. and Lee, W. (2005) Disaggregate journey-to-work data: implications for excess commuting and jobs–housing balance, *Environment and Planning A*, 37, pp. 2233–2252.

Peng, Z. R. (1997) Jobs–housing balance and urban commuting, *Urban Studies*, 34, pp. 1215–1235.

Rodríguez, D. (2004) Spatial choices and excess commuting: a case study of bank tellers in Bogotá, Colombia, *Journal of Transport Geography*, 12, pp. 49–61.

Scott, D. M., Kanaroglou, P. S. and Anderson, W. P. (1997) Impacts of commuting efficiency on congestion and emissions: case of the Hamilton CMA, Canada, *Transportation Research Part D*, 2, pp. 245–257.

Shen, Q. (2000) Spatial and social dimensions of commuting, *Journal of the American Planning Association*, 66, pp. 68–82.

Sultana, S. (2005) Racial variations in males' commuting times in Atlanta: what does the evidence suggest?, *The Professional Geographer*, 57, pp. 66–82.

Wang, F. (2001) Explaining intra-urban variations of commuting by job accessibility and worker characteristics, *Environment and Planning B*, 28, pp. 169–182.

White, M. J. (1988) Urban commuting journeys are not wasteful, *Journal of Political Economy*, 96, pp. 1097–1110.

Wilson, A. G. (1970) The use of the concept of entropy in system modeling, *Operation Research Quarterly*, 21, pp. 247–265.

Yang, J. W. (2005) The commuting impacts of spatial decentralization: a comparison of Boston and Atlanta, *Journal of Regional Analysis and Policy*, 35, pp. 69–78.

Yang, J. W. and Ferreira, J. R. (2005) Evaluating measures of job–housing proximity: Boston and Atlanta, 1980–2000, in: K. Krizek and D. Levinson (Eds) *Access to Destinations*, pp. 171–193. Oxford: Elsevier Ltd.

Yang, J. W. and Ferreira, J. R. (2007) Choices vs. choice sets: a commuting spectrum method for representing job–housing possibilities, *Environment and Planning B* (forthcoming).